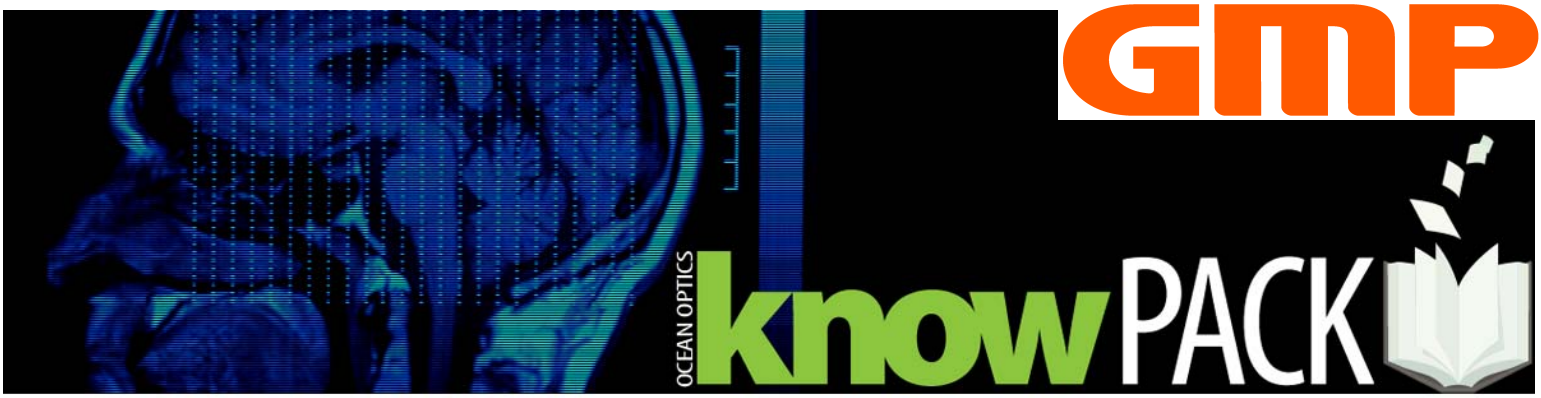

Non-Invasive Reflection Measurements of the Skin, Assessing Sampling Depth by Using Skin Surrogates

Overview

Blood analysis is generally accomplished by taking at least one blood sample which then requires additional sample handling and preparation. Reagents may need to be added and other physical operations performed such as centrifugation of the sample. This time-consuming process delays the proper diagnosis. Several spectrometric techniques aimed toward noninvasive measurements of blood and tissue help with fast diagnosis. By providing analyte concentrations expeditiously, patient inconvenience is virtually eliminated. These noninvasive measurements are predominantly beneficial when the measurements are required frequently and fast results are needed for prompt and accurate diagnosis.

One of the most common, noninvasive tests is the transcutaneous determination of glucose in blood by NIR or Raman spectroscopy. For these kinds of measurements, the skin is considered to be an optically dense scattering material. Basic noninvasive measurements of hemoglobin using a reflection probe and tungsten halogen source indicate that sampling depths are sufficient to monitor changes in the oxygenation state of hemoglobin contained in blood vessels beneath the skin. To address the question of how deep light penetrates during non-invasive reflection measurements of the skin, we used colored ceramic tiles to simulate material below the skin as well as using beef and chicken breast sliced to different thicknesses as surrogates to mimic varying depths of skin.

Experimental Set-up

An Ocean Optics USB2000 Spectrometer is ideal for reflectance measurements from 200-850 nm. The spectrometer's configuration for these measurements includes a Grating #1, (which has peak efficiency at 300 nm), an OFLV Long Pass Order Sorting Filter, L2 Light Collecting Lens, and a 50 um slit. The built-in OFLV-200-850 Order-Sorting Filter eliminates second- and third-order effects. As the excitation source we used an LS-1 Tungsten-Halogen Light Source.

As mentioned before, we used colored ceramic tiles to simulate color-absorbing material below the skin. The beef and chicken breast slices provided surrogates of varying depths of skin. Reference measurements included a white tile alone with other trials using both the meat and the white tile as a reference. A QR400-7 UV/VIS

Reflection Probe with a probe holder STAGE was positioned at 90 degrees relative to the sample.

Figure 1 shows the overall proposed experimental set-up:

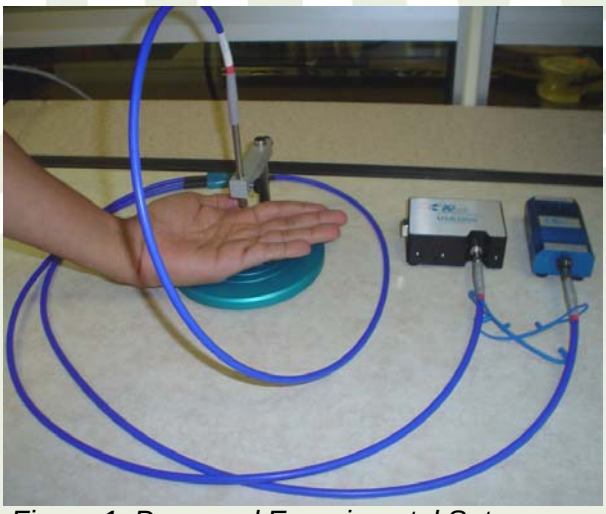

Figure 1: Proposed Experimental Set-up

The experimental parameters for all the tests included an integration time of 3 to 18 msec, measuring averages from 10 to 25 msec, and boxcar smoothing of 3.

Results

Baseline reflection spectra from the colored tiles served to determine the impact of tile color on the shape of the reflection spectra. The data for the colored tiles are shown in Figure 2.

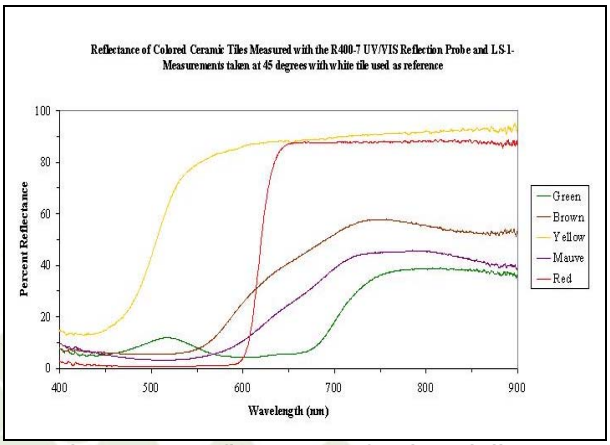

Figure 2: Reflectance of colored tiles obtained at 45 degrees

Note the different spectra depending on the tile color. A white tile served as the reference for these measurements. In this case, we took measurements at 45 degrees relative to the sample to avoid specular reflection from the shiny tiles using an RPH-1 Reflection Probe Holder.

For the tests made with meat as shown in Figure 3, the probe was positioned 90 degrees relative to the sample.

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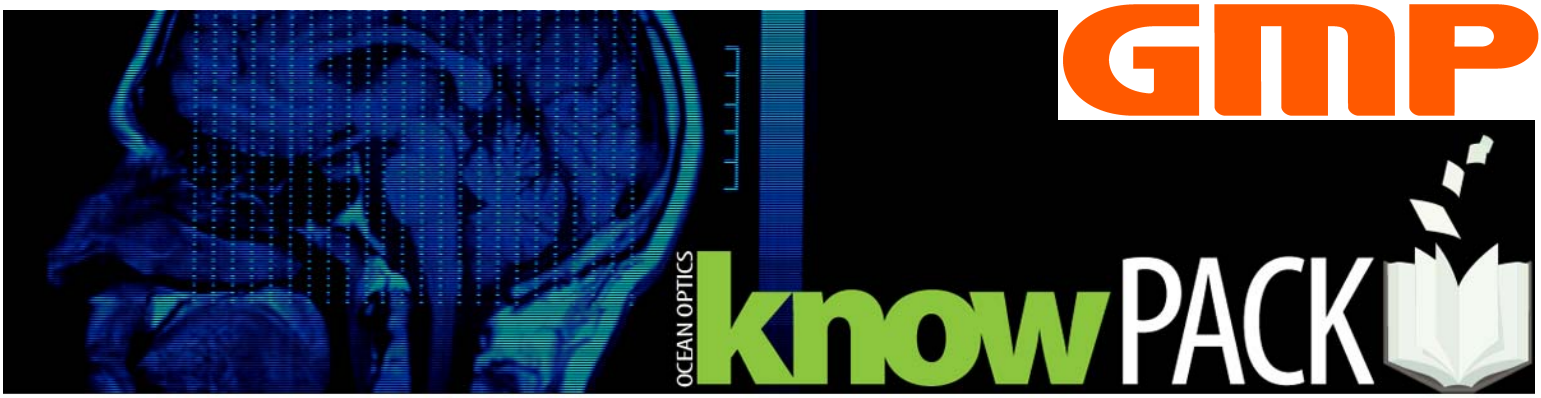

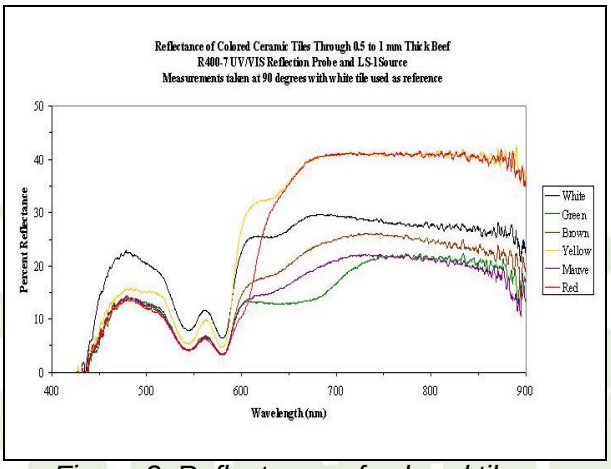

Figure 3: Reflectance of colored tiles through 0.5 to 1.0 mm thick beef slices

Note the strong absorption in the region between 500 and 600 nm. These peaks were most likely due to the presence of high concentrations of Myoglobin in the sliced beef. When comparing the plot shown in Figure 3 for reflectance through beef with the graph shown in Figure 2 (reflectance of the ceramic tiles) we can observe similar shapes and trends due to tile color in the region from 600 to 900 nm. The beef slice thickness in these experiments was approximately 0.5 to 1 mm thick.

When using a thicker piece of beef (approximately 3 mm), the spectra did not show any evidence of the colored tiles beneath the meat. As shown in Figure 4, the spectra obtained in this case are all very similar in shape and magnitude. As shown in Figure 5, when a different, less fatty piece of meat was used, the spectra are different from those shown in Figure 4 but the differences did not appear to be related to the color of the tiles.

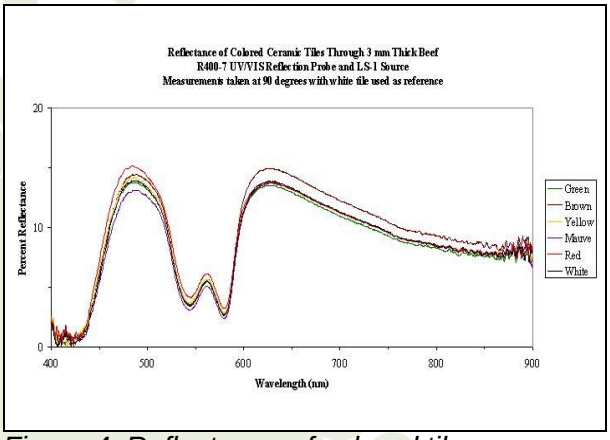

Figure 4: Reflectance of colored tiles through 3.0 mm thick fatty beef slices

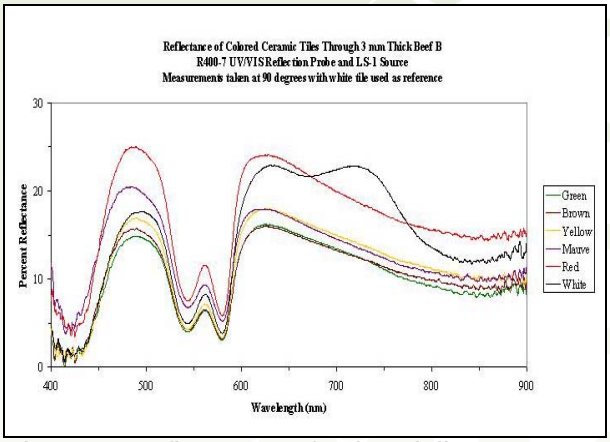

Figure 5: Reflectance of colored tiles through 3.0 mm thick lean beef slices

The results for colored ceramic tile reflectance through chicken were not consistent with either the ceramic tile or the beef and ceramic tile spectra. As shown in Figure 6, the spectral trends suggested that we were not seeing tile color through the chicken. Note that the absorption band from Myoglobin is much lower in chicken than than in beef due to the expected lower levels of Myoglobin found in poultry. The chicken slices used for this test were approximately 1 to 2 mm thick.

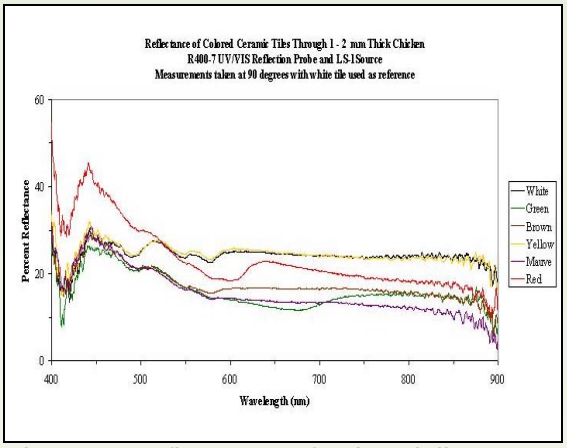

Figure 6: Reflectance of colored tiles through 1.0-2.0 mm thick chicken slices

Figure 7 shows the spectra for various types of beef and reflection through fat (absorbance not as significant). Note the presence of a strong absorption band around 650 nm for the older beef. This peak is most likely related to the presence of oxidized Myoglobin and Hemoglobin in the older sample. This spectrum also had an interesting shoulder that occurred near 500 nm. Measurements for the thick slice of beef yielded spectra that did not contain the doublet expected between 500 and 600 nm (consistent with the presence of deoxygenated Hemoglobin and Myoglobin).

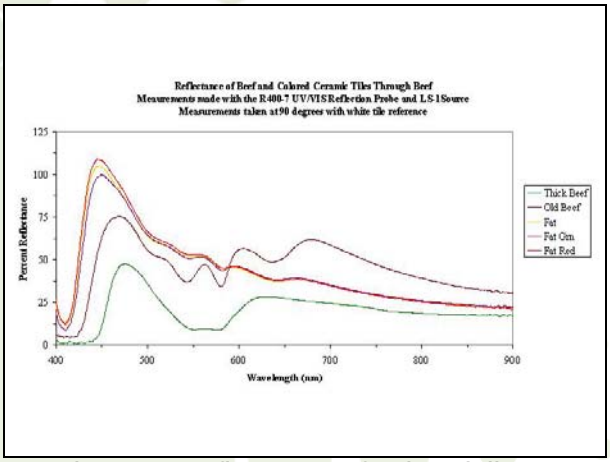

Figure 7: Reflectance of colored tiles through different kinds of beef (aged, fatty, lean, and ground)

Conclusions

The first set of trials with 0.5 to 1 mm beef and 1 to 2 mm chicken, reflectance measurements through a very thin section of meat (approximately 1 mm) suggested that colored ceramic tiles are detectable through the beef slices. Reflectance through chicken did not yield the same recognition of the colored ceramic tiles beneath the chicken.

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The difference in detection was due to the fact that the chicken slices were thicker than the cross section of beef. The same effect resulted from the measurements with 3 mm thick beef which showed that the colored tiles were not detected with a thicker piece of beef.

These results suggest that the light from the LS-1 is not powerful enough to obtain a reflection from the colored tiles when the meat (steak and chicken breast) is more than 1 mm thick and that we might need a more powerful light source such as the HL-2000 Tungsten Halogen light source.

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